Coastal Aerosol Distribution By Data Assimilation

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LONG-TERM GOAL

The long-term goal of this research is to develop an initialization scheme for a multi-dimensional, predictive aerosol model in coastal regions. The initialization scheme will have global coverage and include data gathering, quality control and data assimilation of the available aerosol observations, including satellite aerosol retrievals, ground-based remote sensing, point measurements, and the previous aerosol forecast.

OBJECTIVES

The objectives of this program are to (1) investigate and evaluate the existing and proposed aerosol retrievals from satellites for applicability to aerosol model initialization and (2) develop and test aerosol analysis and data assimilation techniques using satellite and other aerosol measurements.

APPROACH

The approach to the problem of aerosol and Electro-Optical (EO) extinction prediction follows that used in numerical weather prediction, namely real-time assessment and first-principle modeling. A predictive model requires the initial spatial distribution of the aerosol field including composition, concentration, and size distribution. Sensors and retrieval techniques exist for obtaining the aerosol optical depth and some information about particle size. The remotely sensed aerosol properties typically are vertical integrals and are generated at horizontal resolutions ranging from one kilometer to one degree. An objective analysis method is being devised to merge these 2-D distributions with point measurements and model constraints to produce a three-dimensional description of aerosols.

WORK COMPLETED

A program to retrieve aerosol optical depth from AVHRR satellite data has been implemented at Naval Research Laboratory (NRL) Monterey. It is run daily using the AVHRR 1-km data for the East Pacific available to NRL from Naval Postgraduate School (NPS).

AVHRR Global Area Coverage (GAC) data are being received daily from Naval Oceanographic Office (NAVO) for use in implementing optical depth retrieval and fire detection algorithms.

Dust and smoke have been added to the global version of the NRL Aerosol Analysis and Prediction System (NAAPS). The US Geological Survey (USGS)/NRL land use database has been used to determine dust source regions for the entire globe for use in NAAPS with great success. The same

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database will be used to determine surface roughness for diagnosing surface stress from Navy Operational Global Atmospheric Prediction System (NOGAPS) fields of surface wind speed. (The current NOGAPS stress field contains a dynamic component for simulating the effects of gravity wave breaking aloft and should not be allowed to contribute to dust mobilization.

The NOAA AOD (Aerosol Optical Depth) product is received in digital form each day and compared pixel-by-pixel with NAAPS. This comparison quantified what we knew from subjective comparisons: without biomass smoke sources, NAAPS was missing some of highest optical depths observed in the world. The GSFC (Goddard Space Flight Center)/TOMS (Total Ozone Mapping Spectrometer) AI (Absorbing Aerosol Index) is now received and will be used for the same comparison in the near future.

In response to the shortcoming regarding smoke, the ABBA (Automated Biomass Burning Algorithm) product for fire detection in South America based on GOES data is now received four times daily at NRL/MRY from University of Wisconsin. This product is used to specify smoke sources in NAAPS. A historical dataset (1993) for fires in Africa, based on AVHRRR data, was received from ESA and is used to specify smoke sources in Africa. A real-time product may be available next year. A program to detect biomass fires from NAVO AVHRR GAC data has been ported to NRL and is being implemented to provide global coverage for smoke sources.

Several new areas were added to the NAAPS web page (http://www.nrlmry.navy.mil/aerosol): Australia, North America, Eastern U.S., South America, and the Caribbean. A new product was added (in addition to the global smoke and dust products) where NAAPS is displayed with NOAA AOD and TOMS AI for the Mediterranean region. We have also added a page for Bahrain that brings together in one place the data from the GSFC sunphotometer located at Bahrain with NOGAPS, COAMPS, and NAAPS simulations.

An algorithm for estimating extinction from surface synoptic reports of visibility, weather and humidity was developed by Washington University and will be implemented soon in NAAPS for validation and initialization.

RESULTS

NAAPS has been run daily for the entire fiscal year producing realistic simulations of the global distribution of sulfate, dust, and smoke aerosols. It is the only model in the world with this capability and run with this frequency. NAAPS has revealed a higher-than-expected frequency of cases of inter-continental aerosol transport. These include the transport of Asian dust and pollution to North America, and in some cases to the Atlantic Ocean. NAAPS also reveals transport of biomass smoke from South America to Africa, from Africa to South America, and from Africa to Australia. An example of this intercontinental transport of smoke and the accuracy of NAAPS is shown in Figure 1 where the TOMS AI is compared with NAAPS optical depth for September 10, 1999. South American smoke has reached the Greenwich Meridian and will continue to Africa over the next several days. African smoke has nearly reached Australia. In TOMS, there appears to be a break in the plume headed for Australia but this is due to the presence of water clouds, which inhibit the AI retrieval. The NAAPS simulation clearly shows that the area of high AI at 30S, 90E is in fact a part of the African plume. Also seen in both images is a Saharan dust outbreak (green shades). The sulfate aerosol plumes seen in NAAPS (red shades) do not appear in the TOMS absorbing AI retrieval because sulfate is non-absorbing.

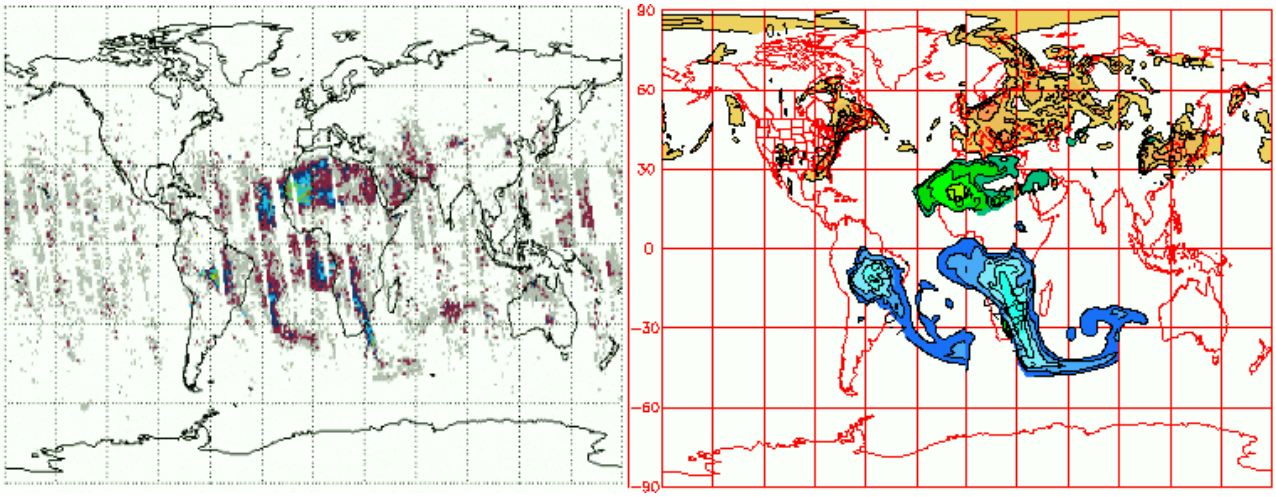

Figure 1. Left panel: GSFC TOMS AI for September 10, 1999, shows distribution of absorbing aerosols. Right panel: NAAPS simulated aerosol optical depth for September 10, 1999 showing distribution of sulfate (reds), dust (greens), and smoke (blues) at optical depths contoured at 0.1, 0.2, 0.4 etc.

NAAPS provided realistic simulations of the near-record-levels haze/pollution episode coinciding with the crash of the plane piloted by J. F. Kennedy Jr. (Prospero et al., 1999). The SEAWIFS imagery for the day (Figure 2.) shows an intense area of haze leaving the continent with an axis along Long Island Sound then turning northeast along Nova Scotia. NAAPS produces a similar distribution, but more importantly, the three-dimensional fields allow an analysis of the vertical distribution, when combined with NOGAPS fields. The area was dominated by a deep, dry, polluted air mass with near-neutral stability (not shown), in contrast to early speculation that visibility was reduced by a deep, moist, marine layer. The NAAPS simulation and analyses were provided to the National Transportation Safety Board (NTSB) and will be used verbatim in their report on the environmental conditions surrounding the crash.

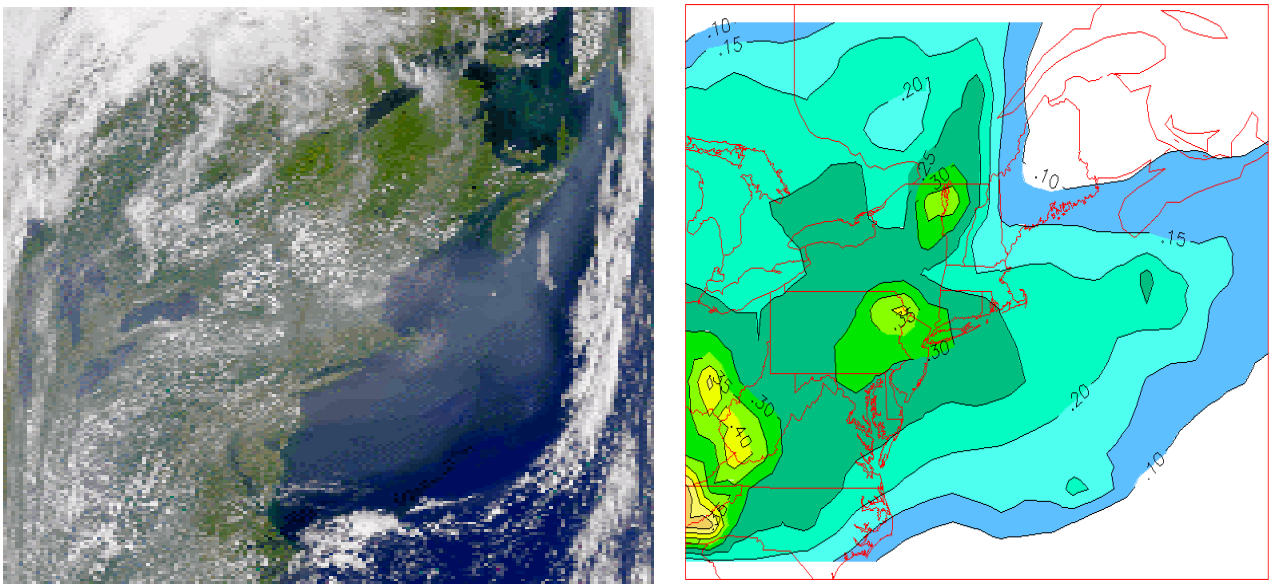

Figure 2. Left panel: SEAWIFS visible imagery for 1630Z, June 16, 1999; right panel: NAAPS simulation of sulfate aerosol optical depth for 0000Z June 17, 1999.

NAAPS provided realistic simulations of heavy dust in Jebel Ali, United Arab Emigrates (U.A.E.), which caused a one-day delay in the port call of the U.S.S. Carl Vinson in February 1999. The event lasted less than a day, yet NAAPS captured the timing and location of the event.

NAAPS provided realistic simulations of North American dust storms in West Texas and Mexico in January 1999, at White Sands in April 1999 and West Texas in May 1999 (Gill et al, 2000). In the January case, NAAPS accurately simulated the production of dust and advection to the east-southeast across the Gulf of Mexico and Florida then out over the Atlantic. In the May case, NAAPS accurately simulated the dust advection to the northeast to the Ohio River Valley.

IMPACT/APPLICATION

Presently, NAAPS produces simulations of the current global aerosol distribution. In the near future, NAAPS will run in a predictive mode and help to satisfy the Navy's long-term goal of a predictive capability for aerosols and EO propagation. This research also provides tools for the 6.1 and 6.2 aerosol research communities and the academic community. Over the past year, as NAAPS has been discovered, collaborations have been initiated between NRL and University of Miami, State of Vermont, University of Colorado, Texas Tech. University, and others; NRL has been invited to participate in ACE-Asia; and NAAPS simulations were used to direct NASA to the optimum viewing region for an upcoming shuttle-borne aerosol program.

TRANSITIONS

The NAAPS simulations and retrieval techniques can soon provide operational aerosol products showing the distribution of anthropogenic, smoke, dust, volcanic ash and other aerosols that can be dissemination to the fleet for use in tactical, strategic and defense planning, for use in dust screening in SST retrievals and in Electro Optical Tactical Decision Aid (EOTDA) validation and development.

RELATED PROJECTS

The NRL 6.1 Coastal Aerosol Processes ARI (BE-033-02-4K) and NRL BE-35-2-18, Mesoscale Modeling of the Atmosphere and Aerosols use NAAPS and the satellite retrievals for investigations and validation. When developed, the operational retrievals and the data assimilation product will be invaluable to these programs. This work is also relevant to 6.4 efforts in EOTDA evaluation and aerosol measurement (PE 0603207N).

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